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## COMPLIANCE WITH SPORT FISHERY REGULATIONS IN MINNESOTA AS RELATED TO REGULATION AWARENESS

## ACCOUNTING FOR MULTILEVEL DATA STRUCTURES IN FISHERIES DATA USING MIXED MODELS

**Sneak Peek!**
SEE PAGE 199.

# Compliance with Sport Fishery Regulations in Minnesota as Related to Regulation Awareness

**ABSTRACT:** We quantified angler party awareness of regulations for 35 Minnesota fisheries using creel surveys. On average, 14% (range = 0–48%) of angler parties were unaware a regulation was in effect for a particular fishery, while 78% (range = 27–100%) of angler parties were aware a regulation was in effect. Awareness varied within and across regulated species: black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieui*), and walleye (*Sander vitreum*). Greatest mean awareness (89%, range = 80–95%) was observed among smallmouth bass fisheries, while lowest mean awareness (70%, range = 52–82%) was observed among largemouth bass fisheries. Awareness was typically lower for fisheries regulated by complex regulations (e.g., slot limits) and for recently implemented regulations. Angler party awareness appeared to be associated with a number of angler demographic characteristics (e.g., days fished on lake and angler residency). Unaware angler parties were significantly more likely to harvest illegally-sized fish among black crappie, largemouth bass, and walleye fisheries, and for all fisheries combined. Fisheries management agencies may need to reevaluate education and communication efforts in order to improve angler awareness of regulations.

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## INTRODUCTION

The effectiveness of fisheries regulations in realizing management goals depends on angler compliance with regulations (Gigliotti and Taylor 1990), and angler awareness of those regulations is a potential contributing factor to angler compliance (Martin 1995; Schill and Kline 1995; Pierce and Tomcko 1998). Nominal levels of angler noncompliance with regulations may impede fisheries management goals (Gigliotti and Taylor 1990), so informing anglers of fisheries regulations is essential for their success. Fishery management agencies use several techniques to inform anglers of regulations (Martin 1995; Pierce and Tomcko 1998; Sullivan 2002; NJDFW 2004). In Minnesota, information on statewide and local (i.e., specific water body) fisheries regulations is primarily provided to anglers through an annual regulation synopsis or handbook. For lakes with fisheries regulations that deviate from general statewide regulations, signs are posted at public access sites to alert anglers of special regulations. Minnesota fisheries managers also disseminate lake specific regulation information to the public via pamphlets, public meetings, promotional fishing gear, newspaper articles, radio, and television.

Minnesota Department of Natural Resources creel clerk interviews an angling party at the completion of their fishing trip.

Although considerable effort has been devoted to informing anglers of regulations, little attention has been directed at evaluating angler awareness of regulations. Martin (1995) found that angler awareness of slot limit regulations imposed on two largemouth bass (*Micropterus salmoides*) fisheries in Delaware appeared to be low (40–51%), and Schill and Kline (1995) documented moderate to high angler awareness (75–100%) of regulations imposed on cutthroat trout (*Oncorhynchus clarki lewisi*)

fisheries in Idaho. Anecdotal evidence such as comparisons between lengths of fish harvested relative to size limits, ancillary comments of anglers made to creel clerks and conservation officers during interviews, and biologists' perceptions of fisheries have been used to speculate on the levels of angler awareness among fisheries and the relative contribution of angler awareness to overall angler noncompliance of regulations (e.g., Martin 1995; Pierce and Tomcko 1998; Sullivan 2002). For example, despite extensive efforts to inform anglers of slot-limit regulations for a number of northern pike (*Esox lucius*) fisheries in Minnesota, monitored using tag return data, estimates of angler noncompliance were high (creel survey, 7–19%; voluntary angler tag returns of harvested protected-sized fish, 5–29%; Pierce and Tomcko 1998). Based on the assumption that anglers who knowingly harvested illegally-sized fish would not return tags, and given the strong support for protected slot limits among anglers, Pierce and Tomcko (1998) suggested that voluntary tag returns from illegally harvested fish represented a lack of angler awareness of regulations. Studies directly evaluating angler awareness and its relationship to angler noncompliance are needed.

As with other factors purported to contribute to angler noncompliance (i.e., angler indifference and fish length measurement error; Sullivan 2002; Page et al. 2004), regulation awareness may be dependent on fisheries characteristics and angler demographics. Schill and Kline (1995) found that angler knowledge of regulations for trout fisheries in Idaho varied across angler demographic groups (e.g., age and residency), and also among fisheries managed with regulations of different complexities (size and bag limit regulations verses catch-and-release regulations). Currently, regulations are highly variable across the state of Minnesota. Over 160 lakes in Minnesota possess special regulations that deviate from statewide regulations. Often multiple species are regulated within a given lake, and regulations typically differ across the state for a given species. Differences in regulation awareness across angler groups and fisheries not only present a challenge to managers, but they also represent deficiencies in the dissemination of regulation information to the angling public.

Understanding the characteristics of angler awareness of regulations would be beneficial in developing effective strategies for communicating information about regulations, tailoring efforts to better educate anglers to regulations, and for predicting which fisheries (e.g., species regulated, regulation type) may exhibit high rates of noncompliance. Further, information on angler awareness may be helpful in clarifying how angler ignorance, indifference, and fish length measurement error relate to overall noncompliance. For this study, we evaluated angler awareness of regulations across numerous fisheries in Minnesota. Using creel data collected from fisheries that possessed length-based regulations, we (1) quantified levels of angler awareness across fisheries representing multiple types of regulations and fish species; (2) evaluated relationships between angler demographics, fisheries characteristics, and angler awareness; and (3) compared levels of angler awareness to levels of noncompliance among fisheries.

## METHODS

In an effort to evaluate the efficacy of various regulations for altering size structures of sport fish populations in Minnesota, the Minnesota Department of Natural Resources (MNDNR) implemented regulations on multiple sport fish fisheries (Figure 1; Table 1). Minimum (all fish less than a given length must be released), maximum (all fish greater than or equal to a given length must be released), and protected slot limit (all fish within a given length range must be released) size regulations, along with catch-and-release regulations, were implemented to regulate 5 sport fish species (black crappie *Pomoxis nigromaculatus*, largemouth bass, northern pike, smallmouth bass *Micropterus dolomieui*, and walleye *Sander vitreus*) on 38 lakes across Minnesota (Figure 1; Table 1). Multiple methods were used to promote angler awareness about regulations, including a regulation handbook developed and distributed by the MNDNR, signs posted at public access sites, and various news outlets (e.g., newspapers, natural resource magazines, etc.). Fish population responses to regulations were evaluated over a 5–10 year period (i.e., regulated years, between 1995 and 2004) using data collected by area fisheries management personnel during routine population assessments of regulated fish species and lake surveys. Creel surveys were also performed on several lakes to evaluate changes in angler effort, catch, and compliance rates for regulated fisheries.

### *Data Collection*

A standard roving creel survey design was used to collect data on angler awareness. Creel surveys were stratified by day-type (weekday and weekend) and season (e.g., by month). Creel data was typically collected from incomplete angler trips. Twenty-nine creel surveys were performed between 2000 and 2004, of which all but five were performed during the open water season (May–September, Table 1). Creel surveys were performed on 21 lakes representing 5 sport fish species (walleye, $N$ = 13; largemouth bass, $N$ = 8; smallmouth bass, $N$ = 4; black crappie, $N$ = 6; northern pike, $N$ = 4; Figure 1), and 18 different regulations (Table 1). We qualified each creel survey as an assessment of a separate fishery ($N$ = 35), and evaluated angler responses to awareness accordingly. For creel surveys performed on lakes where two species were regulated, we considered these creel surveys an assessment of two separate fisheries. Two lakes, Chisago-Lindstrom and Green lakes, each possessed two regulated fisheries (Chisago-Lindstrom Lake: walleye and largemouth bass; Green Lake: walleye and black crappie). Five lakes evaluated in this study were within the boundaries of the 1837 Treaty territory (Figure 1). This territory represents the region ceded to the United States by Ojibwe (Chippewa) tribal bands under the conditions that tribal members retained hunting and fishing rights within the territory. Harvest regulations within the territory were developed annually, and fisheries selected for regulation were dependent on expected tribal fishing interests and angler fishing effort. Due to low numbers of anglers interviewed (< 50) during creel surveys for Flour, Hungry Jack, Pike, and Two Island lakes, we combined creel data collected across multiple years for each lake (1999 and 2002 for Two Island Lake; 2000 and 2002 for Pike Lake, 2001 and 2002 for Hungry Jack and Flour lakes). We also combined data from creels performed on North and South Lida lakes, given that a channel through which both fish and anglers can readily traverse connects these lakes.

Standard creel survey questions asked by creel clerks during angler interviews were supplemented with questions designed to evaluate angler awareness of length limit regulations. Anglers were asked:

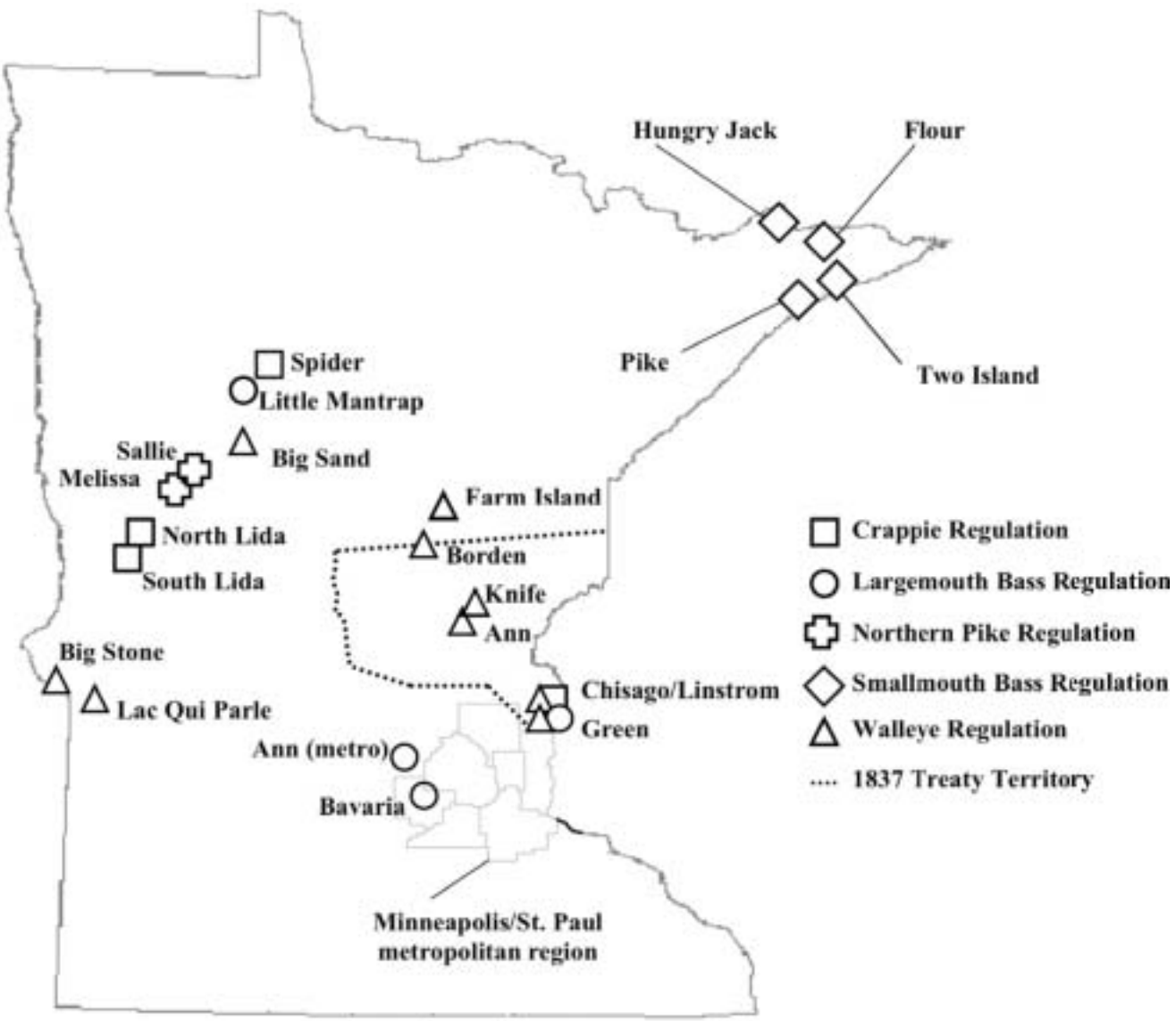
1. How many days do you typically fish in a given year (i.e., last 365 days)?
2. Have you fished this lake before and if so, how many days in the last year?
3. Are you aware that there is a special regulation in effect on this lake?
4. Can you recite the regulation (species and size limit)?

We used angler parties to evaluate awareness. Questions 1 and 2 were asked to each angler within a party; however, we only evaluated responses from the initial responding angler (first angler documented in the interview, herein lead angler).

Responses to questions 1 and 2 were usually similar across all anglers within a party, or the lead angler was typically more experienced (i.e., fished more days) than other anglers in a party. Questions regarding days fished annually and on the given lake were asked to gauge the experience and potential level of exposure to a specific regulation for the entire angler party. Creel clerks were instructed to ask regulation questions (3 and 4) to the entire party, and answers to these questions were used to categorize angler party awareness of fisheries regulations. Angler parties that were aware of the regulation for a given fishery, and were able to correctly recite the regulated species and size limit were designated as "completely aware." Angler parties that were aware that a regulation was in place, but could not correctly name the regulated species and/or could not correctly recite the size regulation were designated as "incompletely aware." Angler parties that answered no to question 3 were classified as "unaware." In addition, to identify and evaluate information sources used by anglers, angler parties that were aware of a given regulation were asked where they had learned of the regulation. Regulation questions were asked to nearly all angler parties encountered within a creel survey, or angler parties were randomly questioned. Creel clerks were instructed not to repeat angler awareness questions to angler parties that were previously interviewed earlier during the survey.

Local fisheries managers had ultimate discretion as to how angler awareness questions were integrated into creel surveys. In conjunction with standard questions regarding angler catch and demographics, managers typically queried anglers on a variety of fisheries topics (e.g., angler satisfaction), and therefore were required to balance the number of additional questions evaluating angler awareness with interview time constraints. Hence, to maximize the number of anglers interviewed during a creel survey, anglers were not asked the full complement of demographic questions during some creel surveys (Table 1).

We evaluated awareness against a number of angler demographic characteristics. Since demographic characteristics were usually consistent among anglers within an angler party, we evaluated only the demographic data associated with the lead angler. We also only evaluated those angler party



interviews where the demographic data of the lead angler was complete. For each evaluated fishery, we compared angler awareness of regulations among lead angler ages (lead angler was usually the older angler), species of fish targeted (regulated vs. non-regulated), day-type fished (weekday vs. weekend/holiday), number of anglers in the party, and residency of the lead angler (local vs. non-local, and metropolitan vs. non-metropolitan, as defined below). Based on the age of the lead angler, angler parties were grouped into six age categories representing ages ranging from 11–19, 20–29, 30–39, 40–49, 50–59, and ≥ 60 years. For the number of days fished during the past year, angler parties were categorized as fishing 0–10, 11–20, 21–50, and > 50 days. For number of days fished on the regulated lake in the past year, angler parties were categorized as fishing 0, 1–7, 8–21, and > 21 days. For the Lake Ann (metro) and Lake Bavaria fisheries, area fishery biologists directing the associated creel surveys for these lakes elected to group the number of days fished during the past year, and number of days fished on the regulated lake during the past year as < 5, 5–10, 11–20, 21–50, and > 50 days, and 0, < 5, 5–10, 11–20, 21–50, and > 50 days, respectively. We categorized number of anglers in each party as 1, 2, 3, and ≥ 4 anglers. Using zip code analysis software (Melissa Data Corp.), we used zip codes provided by anglers and the zip codes of the community nearest to the surveyed lake to estimate the distance traveled

**Table 1.** Estimates, in percentages, of angler noncompliance and angler party awareness for 29 Minnesota fisheries regulated by length limits. Creel Year refers to the year anglers were queried on awareness during creel surveys. Estimates of noncompliance are based on percent of total harvest in numbers that consists of illegally harvested fish (Total Harvest), percent of protected fish caught that were harvested and not released (Protected Fish Harvested), percent of angler parties harvesting fish that also harvested protected fish (Party Harvest), and the percent of parties that caught protected fish that also harvested protected fish (Party Protected Harvest). Numbers in parentheses represent the number of fish or angler parties evaluated for each estimate. Complete Awareness was defined as the percentage of angler parties that were aware of a regulation and could recite the regulation, Incomplete Awareness was defined as the percentage of angler parties that were aware of a regulation but did not know, or could not accurate recite the regulation, and Unaware was defined as the percentage of angler parties that were unaware of a regulation. *N* represents the number of angler parties queried on awareness. BLC = black crappie; LMB = largemouth bass; SMB = smallmouth bass; WAE = walleye, NOP = northern pike, "min" refers to minimum size limit, "max" refers to maximum size limit, and "slot" refers to protected slot limits.

| | | | | | Percent noncompliance | | | | Percent angler awareness | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Species regulated | Regulation implemented | Date regulation implemented | Creel year[1] | Total harvest | Protected fish harvested | Party harvest | Party protected harvest | Complete awareness | Incomplete awareness | Unaware | N |
| Ann[2] | WAE | 16" min | 2000 | 2000 | 42 (37) | 5 (294) | 42 (26) | 9 (118) | 61 | 11 | 28 | 192 |
| Ann (metro) | LMB | No Kill | 1995 | 2000 | 0 (0) | 0 (207) | 0 (0) | 0 (75) | 73 | 0 | 27 | 216 |
| Ann (metro) | LMB | No Kill | | 2001 | 0 (0) | 0 (224) | 0 (0) | 0 (73) | 82 | 0 | 18 | 180 |
| Bavaria | LMB | No Kill | 1995 | 2000 | 100 (1) | 0 (225) | 1 (1) | 2 (64) | 76 | 1 | 23 | 232 |
| Bavaria | LMB | No Kill | | 2001 | 0 (0) | 0 (143) | 0 (0) | 0 (56) | 73 | 0 | 26 | 172 |
| Big Sand | WAE | 18-26" slot | 1995 | 2002 | 4 (138) | 1 (1103) | 5 (109) | 1 (464) | 88 | 8 | 4 | 1177 |
| Big Stone | WAE | 14" min | 1996 | 2001 | 1 (749) | 1 (1201) | 1 (435) | 2 (367) | 92 | 2 | 6 | 547 |
| Big Stone | WAE | 14" min | | 2001-2002w | 0 (16) | 0 (98) | 0 (14) | 0 (53) | 100 | 0 | 0 | 56 |
| Borden[2] | WAE | 20-23" slot | 2000 | 2000 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 27 | 25 | 48 | 241 |
| Chisago-Lindstrom | LMB | 12" max | 1997 | 2000 | 34 (58) | 2 (1557) | 43 (44) | 6 (303) | 67 | 7 | 27 | 475 |
| Chisago-Lindstrom | LMB | 12" max | | 2002 | 100 (1) | – | 100 (1) | – | 52 | 32 | 16 | 160 |
| Chisago-Lindstrom[2] | WAE | 16-20" slot | 2002 | 2002 | 0 (2) | 0 (5) | 0 (2) | 0 (4) | 38 | 46 | 16 | 160 |
| Farm Island | WAE | 16-19" slot | 1996 | 2003 | 7 (312) | 10 (223) | 11 (192) | 18 (120) | 66 | 13 | 21 | 608 |
| Farm Island | WAE | 16-19" slot | | 2004 | 5 (82) | 4 (112) | 7 (58) | 7 (59) | 86 | 1 | 13 | 72 |
| Flour | SMB | 11" max | 1996 | 2001, 2002 | 13 (97) | 13 (184) | 33 (33) | 17 (58) | 80 | 13 | 7 | 96 |
| Green | BLC | 9" min | 1997 | 2000 | 87 (326) | 17 (1927) | 21 (168) | 26 (254) | 55 | 18 | 27 | 399 |
| Green | BLC | 9" min | | 2002 | 31 (85) | – | 38 (24) | – | 75 | 5 | 20 | 117 |
| Green[2] | WAE | 17" min | 2002 | 2002 | 21 (14) | 1 (253) | 38 (8) | 3 (89) | 61 | 19 | 20 | 117 |
| Hungry Jack | SMB | 11" max | 1996 | 2001, 2002 | 25 (106) | 10 (483) | 46 (48) | 20 (111) | 90 | 4 | 6 | 110 |
| Knife[2] | WAE | 18-24" slot | 2000 | 2000 | 5 (191) | 11 (104) | 17 (23) | 14 (65) | 71 | 7 | 22 | 218 |
| Lac Qui Parle | WAE | 15" min | 1996 | 2001 | 0 (336) | 0 (1206) | 1 (163) | 0 (277) | 94 | 3 | 3 | 287 |
| Lac Qui Parle | WAE | 15" min | | 2003 | 1 (409) | 0 (7879) | 1 (219) | 0 (622) | 83 | 13 | 4 | 312 |
| Lac Qui Parle | WAE | 15" min | | 2001-2002w | 6 (12) | 0 (465) | 6 (16) | 1 (130) | 95 | 5 | 1 | 111 |
| Little Mantrap | LMB | 12-18" slot | 1997 | 2002 | 11 (16) | 1 (174) | 17 (12) | 3 (65) | 68 | 11 | 21 | 362 |
| Little Mantrap | LMB | 12-18" slot | | 2003 | 23 (35) | 4 (228) | 25 (20) | 6 (86) | 68 | 8 | 24 | 358 |
| Melissa | NOP | 24" max | 1996 | 2003 | 0 (65) | 0 (126) | 0 (30) | 0 (45) | 97 | 0 | 3 | 380 |
| Melissa | NOP | 24" max | | 2003-2004w | 3 (34) | 2 (54) | 5 (22) | 3 (35) | 76 | 0 | 24 | 94 |
| North and South Lida | BLC | 11" min | 1997 | 2002 | 0 (156) | 0 (226) | 0 (93) | 0 (69) | 99 | 0 | 1 | 1178 |
| North and South Lida | BLC | 11" min | 1997 | 2002-2003w | 0 (152) | 0 (100) | 0 (63) | 0 (33) | 98 | 0 | 2 | 200 |
| Pike | SMB | 11" max | 1997 | 2000, 2002 | 9 (35) | 4 (82) | 13 (23) | 12 (26) | 95 | 2 | 3 | 92 |
| Sallie | NOP | 24" max | 1996 | 2003 | 4 (47) | 2 (109) | 5 (21) | 3 (40) | 98 | 0 | 2 | 427 |
| Sallie | NOP | 24" max | | 2003-2004w | 0 (19) | 0 (102) | 0 (17) | 0 (62) | 66 | 0 | 34 | 164 |
| Spider | BLC | 10" min | 1997 | 2002 | 26 (47) | 8 (152) | 26 (19) | 23 (22) | 84 | 2 | 14 | 288 |
| Spider | BLC | 10" min | | 2003 | 21 (61) | 7 (200) | 52 (25) | 28 (46) | 90 | 2 | 8 | 247 |
| Two Island | SMB | 11" max | 1996 | 1999, 2002 | 28 (183) | 12 (490) | 39 (77) | 27 (111) | 90 | 7 | 3 | 136 |

[1] All creels are summer creels (typically May–September) unless designated with a "w," which represents a winter creel. Winter creels typically conducted from December–February. Data from multiple creel years combined for SMB fisheries.

[2] Walleye fisheries within the 1837 Treaty region.

(miles) by angler parties to a given lake. Distance traveled to a lake was defined as the number of miles from the center of the zip code area in which a given lake was located to the center of the zip code area where the lead angler resided (e.g., if lead angler's residency and the location of a given lake were within the same zip code, the distance traveled was 0.0 miles). We arbitrarily designated lead anglers that traveled ≤ 10 mi as local anglers, and lead anglers that traveled > 10 mi as non-local anglers. Given the remote locations of Flour, Hungry Jack, Pike, and Two Island lakes (Figure 1), lead anglers that resided within ≤ 50 mi of a given lake were designated as local anglers, and lead anglers that traveled > 50 mi were designated as non-local anglers. In addition, we identified anglers, based on zip code, as either metropolitan or non-metropolitan residents. Anglers were designated as metropolitan residents if they resided within the seven-county metropolitan region (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties; Minneapolis-St. Paul Metropolitan Council 2004) surrounding the cities of Minneapolis and St. Paul, Minnesota.

*Statistical Analysis*

We estimated four measures of angler noncompliance (Table 1). Using catch data collected from all anglers during creel surveys, we calculated noncompliance as:

- Total harvest noncompliance: the percent of harvested fish that were of protected size (as measured and recorded by creel clerks)
- Protected fish harvest noncompliance: the percent of fish of a protected size reported as caught that were subsequently harvested.
- Party harvest noncompliance: the percent of all angler parties that harvested fish that also harvested fish of a protected size.
- Party protected harvest noncompliance: the percent of angler parties that reported catching protected-size fish that also harvested fish of a protected size.

For simplification, we combined angler parties that were designated as unaware with angler parties designated as incompletely aware (herein "unaware" angler parties) for these analyses. We assumed that anglers were truthful about the fish they caught and in their answers to the awareness questions, and that non-reporting bias was negligible since very few anglers refused to be interviewed (< 1%). We visually compared estimates of angler party awareness (complete awareness) to estimates of noncompliance (party protected harvest noncompliance) across and within fisheries to identify trends in the data. We also evaluated relationships between awareness and noncompliance by categorizing angler parties that caught protected-sized fish into four groups based on awareness and compliance (e.g., party protected harvest noncompliance). For each fishery type (i.e., species regulated), angler parties were grouped either as "aware and compliant" (i.e., released protected fish), "aware and noncompliant" (i.e., harvested protected fish), "unaware and compliant," or as "unaware and noncompliant." Fisher's exact tests were performed to determine the probability that noncompliance was greater for unaware angler parties than for aware angler parties. To measure whether there was a propensity for unaware anglers to be less compliant than aware anglers, we calculated the odds ratio of noncompliance of unaware angler parties for angler parties fishing within black crappie, largemouth bass, smallmouth bass, and walleye fisheries, separately, and for all angler parties combined. For the Fisher's exact test and odds ratio analyses, we did not include fisheries where the party protected harvest noncompliance estimate could not be calculated because the number of protected-sized fish caught was low (Borden Lake walleye, $N = 0$; Chisago-Lindstrom Lake walleye, $N = 5$), or where size estimates were not collected for a large number of fish released by anglers (2002 Chisago-Lindstrom Lake largemouth bass; 2002 Green Lake black crappie). We expected that "unaware" parties would be more likely ($P < 0.05$) to harvest protected fish than "aware" parties. Further, we evaluated the overall catch of regulated fish for each fishery to look for patterns in the number and size (means) of fish captured by aware verses unaware angler parties.

Angler party demographics were compared with regulation awareness. Angler party demographics for individual fisheries were analyzed using contingency chi-square analyses. We tested for significant differences ($P < 0.05$) in angler party awareness based on angler residency (local vs. non-local), region of angler residency (metropolitan and non-metropolitan), angler age, days fished in the past year, days fished on a regulated lake in the past year, fish species targeted, day-type, and number of anglers within the party. We expected that angler parties that possessed greater opportunity for exposure to information on regulations would be significantly more likely to be aware of the regulations. That is, angler parties that exhibit greater awareness for a given regulation would consist of members that lived near the regulated lake (i.e., local residents), fished the regulated lake more often, fish in general more often, were older, and targeted the regulated species. We also expected that larger angler parties would be more aware than smaller angler parties. Since a greater proportion of anglers that fished on weekends and holidays appeared to be casual anglers, that is, more generalists and less experienced anglers, we expected that angler parties that fished on the weekends and holidays would be less aware than anglers that fished on weekdays. Given that previous studies have found that anglers from the Minneapolis-St. Paul metropolitan region are generally more educated and progressive in regards to attitudes towards fisheries management issues (Jacobson 1999; Currie and Fulton 2001), we expected that anglers from the metropolitan region would possess greater awareness of regulations than anglers from the remainder of the state. We explored the data for trends or patterns in angler party awareness related to the number of years a regulation was in place (i.e., exposure to regulation), and the complexity of a regulation. Regulations were subjectively assigned a level of complexity based on the potential difficulty in interpretation and the prevalence of the regulation in Minnesota. We assigned regulations in order of increasing difficulty in interpretation as: catch-and-release (easily interpreted), minimum length limits (common, but more difficult to interpret), maximum length limits (uncommon, and potentially difficult to interpret), and slot length limits (uncommon, and difficult to interpret). We expected that angler awareness would be generally greater for fisheries that have been regulated longer, and for fisheries that possessed less complex regulations.

Information sources used by anglers were summarized. We categorized information sources as bait shop, word-of-mouth, MNDNR regulation synopsis, lake signs, resort or fishing guide, newspaper or magazine, pamphlet, MNDNR website, radio, television, or other. Word-of-mouth represented information gained verbally from sources such as friends, family members, or other anglers. Angler responses that were classified as "other" were responses that could not be easily categorized (e.g., creel clerk, conservation officer, public meeting, or names of places or people), or responses where multiple information sources were given. For Lake Ann (metro) and Lake Bavaria fisheries, only word-of-mouth, regulation synopsis, lake sign, and resort or guide categories were used. All other responses were designated as "other." For five fisheries (Big Sand Lake walleye, Little Mantrap Lake largemouth bass, Pike Lake smallmouth bass, Spider Lake black crappie, and Two Island

Lake smallmouth bass), no questions regarding information sources were asked.

## RESULTS

### *Angler Regulation Awareness*

Complete angler awareness varied greatly across fisheries (range = 27–100%; mean = 78%; Table 1). A number of fisheries exhibited complete or nearly complete angler awareness (e.g., Big Stone Lake and Lac Qui Parle walleye, North and South Lida Lake black crappie, and Pike Lake smallmouth bass). On average, angler awareness was lowest among largemouth bass fisheries (range = 52–82%; mean = 70%), and highest among smallmouth bass fisheries (range = 80–95%; mean = 89%). Awareness was most variable among walleye fisheries (range = 27–100%; mean = 74%). For fisheries within the 1837 Treaty region, angler awareness was typically low (range = 27–75%; mean = 56%), and incomplete awareness was high (range = 0–46%; mean = 19%). Complete awareness tended to be greater for fisheries where regulations have been in effect the longest (Figure 2), and incomplete awareness tended to be higher for fisheries regulated with complex regulations such as maximum and slot limits (Figure 3).

### *Angler Noncompliance with Regulations*

Most fisheries appeared to exhibit low noncompliance. Noncompliance based on total harvest ranged from 0–100%, protected fish harvested ranged from 0–17%, party harvest ranged from 0–100% (100%, $N$ = 1), and party protected harvest ranged from 0–28% (Table 1). The highest level of noncompliance, based on party protected harvest, was documented within the 2003 Spider Lake black crappie fishery (28%). All largemouth bass fisheries exhibited low levels of noncompliance (0–6%). The most pervasive noncompliance among regulated species, based on party protected harvest, was documented within smallmouth bass fisheries (12–27%). High noncompliance rates also were documented for the 2002 Spider Lake black crappie fishery (23%) and the 2000 Green Lake black crappie fishery (26%). Comparisons in the catch of regulated species for each fishery revealed that unaware anglers tended to catch fewer regulated fish of smaller size compared to aware angler parties (Figure 4).

### *Awareness and Noncomplaince*

Visual inspection of the data suggested that there was no overall trend between

**Figure 2.** Relationship between proportion of angler parties completely aware of a regulation, and the number of years a regulation was in effect for 35 regulated fisheries in Minnesota. A completely aware angler party was defined as a party that was aware of the existence of a regulation and knew the regulation components (i.e., species and size limit). The number of years a regulation was in effect was defined as the year a regulation was implemented minus the year angler parties were questioned on regulation awareness (i.e., creel year, Table 1).

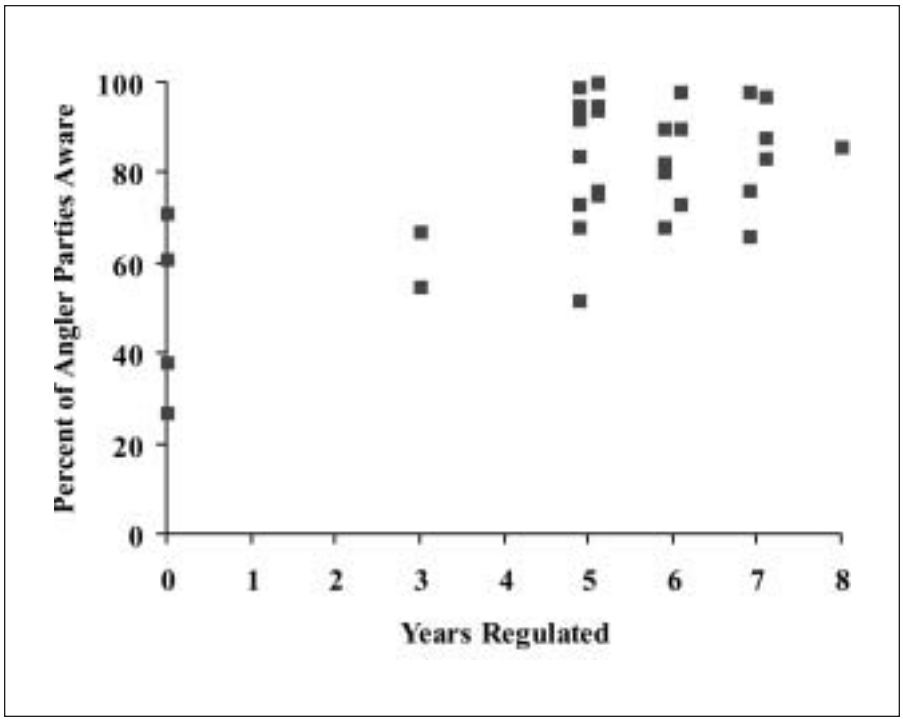
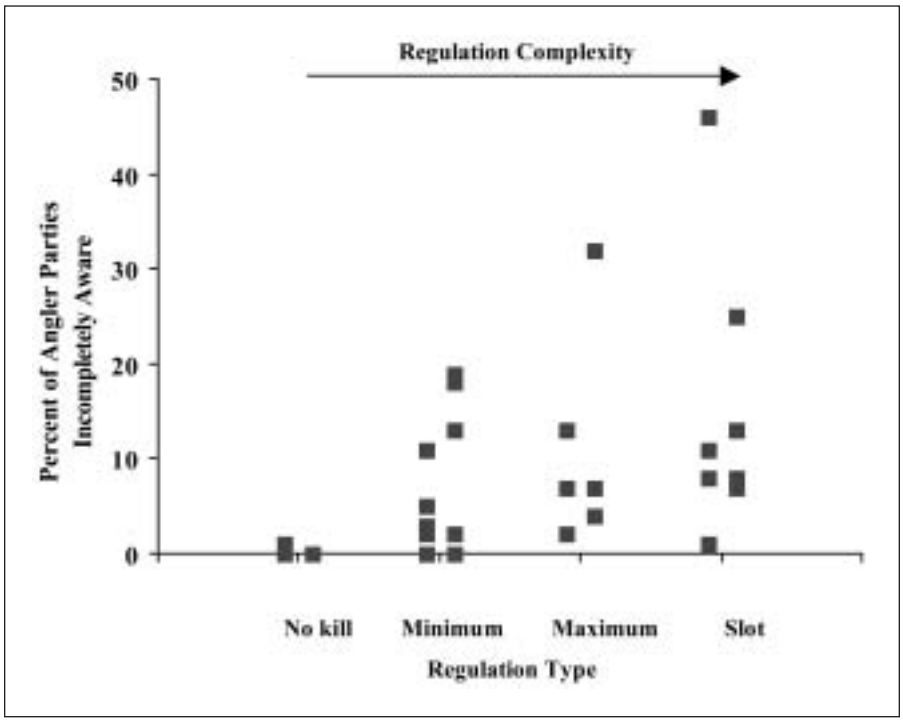



**Figure 3.** Relationship between proportion of angler parties incompletely aware of a regulation and the complexity of the regulation for 31 fisheries in Minnesota. An incompletely aware angler party was defined as a party that was aware a regulation existed, but did not know some or all of the regulation components (i.e., species and size limit). The complexity of a regulation type was inferred based on its potential ambiguity and prevalence among regulation types used throughout the state of Minnesota.



awareness and noncompliance (complete angler party awareness vs. party protected harvest noncompliance; Table 1). Noncompliance appeared to decrease as awareness increased for black crappie, largemouth bass, and walleye fisheries. Fisher's exact-tests for individual fisheries found that the tendency of unaware angler parties to be less compliant than aware angler parties varied greatly across fisheries. For five of the fisheries studied (2001 Big Stone Lake, and Big Sand Lake walleye, 2000 Chisago-Lindstrom Lake largemouth bass, 2003 Farm Island Lake walleye, and 2000 Green Lake black crappie), the proportion of noncompliant parties was significantly higher for unaware parties compared to aware parties ($P = 0.001$; $P = 0.054$; $P = 0.001$; $P = 0.001$; $P = 0.028$, respectively). However, for most fisheries, the documented number of unaware angler parties that captured protected fish was low. The proportion of angler parties that were aware of regulations and harvested protected fish was also generally low (range 0.6–26%).

We found that unaware angler parties were significantly more likely to be noncompliant than aware angler parties among black crappie, largemouth bass, and walleye fisheries, and for all fisheries combined, based on Fisher's exact tests ($P = 0.000$; Table 2 and Figure 5). No significant evidence was found for a relationship between awareness and noncompliance for angler parties among northern pike and smallmouth bass fisheries, however the power to detect a difference was low for these fisheries (25%).

Odds ratio analysis revealed that the propensity of unaware angler parties to harvest illegal sized fish was significantly greater than aware angler parties for black crappie, largemouth bass, and walleye fisheries, and across all fisheries combined ($P < 0.05$). Unaware angler parties were 11.7 times

**Figure 4.** Box-plots summarizing the differences (percent difference) between aware and unaware angler parties in estimates of (a) catch-per-angler party of regulated species, and (b) the mean length of regulated fish species captured. Percent difference was calculated as the catch estimate for unaware angler parties minus the catch estimate for aware angler parties divided by the catch estimate for aware angler parties.

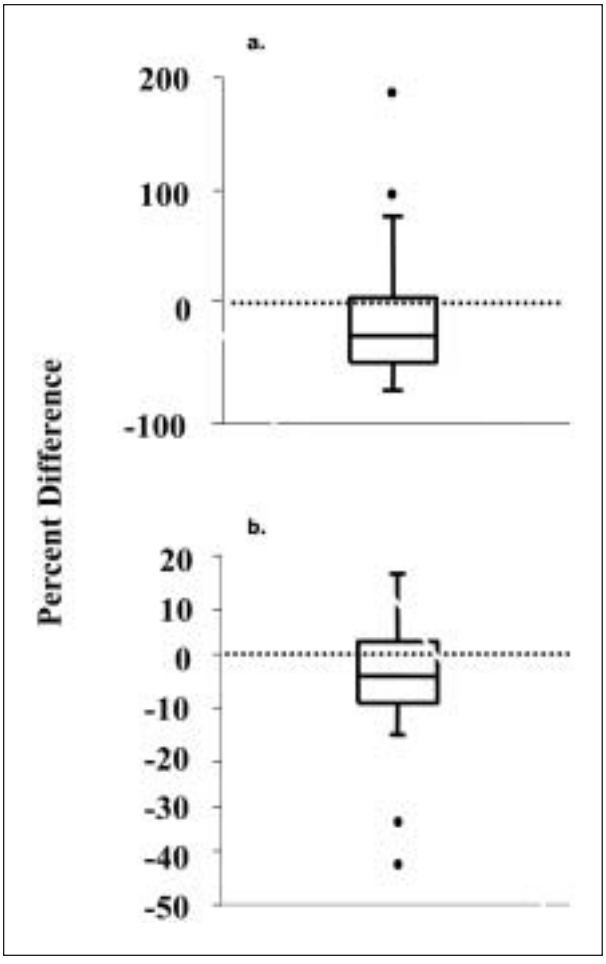
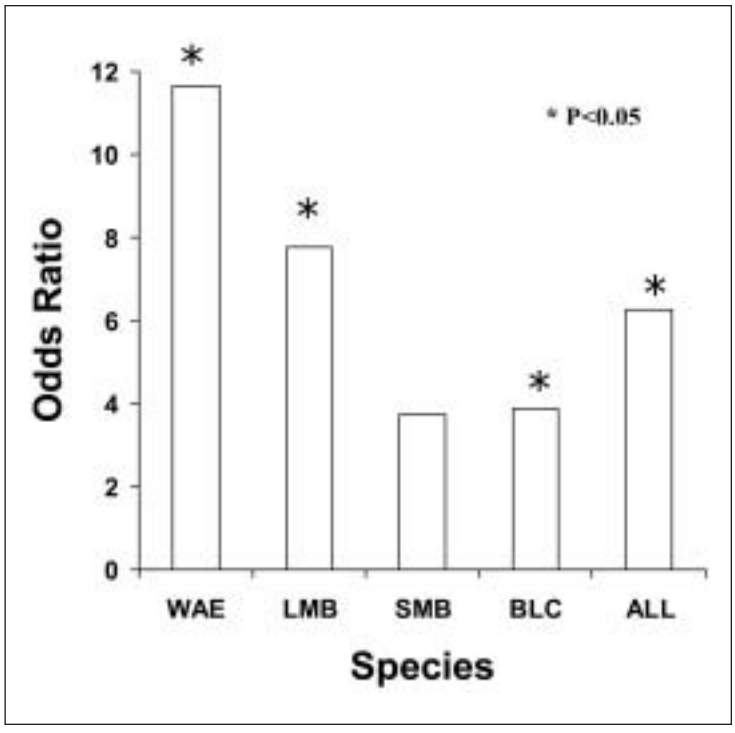



**Table 2.** Number of angler parties catching protected sized fish categorized by their awareness and compliance with regulations. Angler parties were designated as compliant if they released all protected sized fish captured, or noncompliant if any fish of protected size was harvested. P-values for Fisher exact tests used to determine the probability that noncompliance was greater for unaware angler parties than for those angler parties that were aware. BLC = black crappie; LMB = largemouth bass; SMB = smallmouth bass; WAE = walleye; NOP = northern pike.

| | Number of Interviews | | | | |
|---|---|---|---|---|---|
| Fishery | Aware--compliant | Aware-noncompliant | Unaware-compliant | Unaware-noncompliant | Fisher exact test |
| BLC | 263 | 31 | 57 | 26 | **0.000** |
| LMB | 427 | 6 | 110 | 12 | **0.000** |
| NOP | 71 | 0 | 7 | 1 | 0.101 |
| SMB | 135 | 9 | 8 | 2 | 0.152 |
| WAE | 949 | 18 | 95 | 21 | **0.000** |
| All | 1774 | 64 | 270 | 61 | **0.000** |

**Figure 5.** Graph presenting the odds ratios derived by comparing numbers of compliant and noncompliant angler parties among aware and unaware angler parties that captured protected sized fish. Angler parties were grouped by fishery type (i.e., species regulated). Odds ratios represent the propensity for an unaware angler party to be noncompliant compared to an aware angler party (e.g., unaware anglers were 11.7 times more likely to be noncompliant than aware anglers within walleye fisheries). WAE = walleye, LMB = largemouth bass, SMB = smallmouth bass, BLC = black crappie.



more likely to be noncompliant than aware angler parties among walleye fisheries, 7.8 times for largemouth bass fisheries, 3.8 times for smallmouth bass fisheries, 3.9 times for black crappie fisheries, and 6.3 times for all fisheries combined (Figure 5). We were unable to estimate the odds ratio for northern pike fisheries because no aware angler parties interviewed had captured and harvested illegally sized fish.

*Angler Demographics and Awareness*

Angler parties among most fisheries ($N$ = 25) exhibited significant differences ($P$ < 0.05; chi-square analysis) in levels of awareness for at least one of the angler demographic factors evaluated (Table 3), while angler parties within 16 fisheries significantly differed in awareness for multiple demographic factors. Significant differences in angler awareness were most commonly attributed to angler residency (local vs. non-local; $N$ = 11), days fished on the regulated lake ($N$ = 14), and species targeted (regulated vs. non-regulated; $N$ = 8). Angler awareness associated with days fished in a year ($N$ = 7), region of residency (metro vs. non-metro; $N$ = 7), day-type (weekdays vs. weekends/holidays; $N$ = 4), angler age ($N$ = 4), and number of anglers in party ($N$ = 2) differed significantly less

**Table 3.** Significance levels for contingency chi-square analyses evaluating awareness of regulations among angler parties for eight demographic characteristics. Significant differences ($P$ < 0.05) in angler awareness of regulations (complete awareness) are designated in bold. Dashes designate demographic characteristics that could not be evaluated. Species refers to the fish species regulated (BLC, black crappie; LMB, largemouth bass; SMB, smallmouth bass; WAE, walleye; NOP, northern pike). For Regulation Implemented, "min" refers to minimum size limit, "max" refers to maximum size limit, and "slot" refers to protected slot limit. Creel Year refers to the year anglers were queried on awareness during creel surveys. Local anglers defined as anglers residing ≤ 10 miles of regulated lake, and non-local anglers defined as anglers residing > 10 miles from regulated lake. Days fished annually grouped as 0–10, 11–20, 21–50, and > 50 days. Days fished lake grouped as 0, 1–7, 8–21, and > 21 days. Day type grouped by weekday and weekend/holiday. Angler age grouped as 12–19, 20–29, 30–39, 40–49, 50–59, and ≥ 60 years. Species targeted grouped as regulated species and other. Party number grouped as 1, 2, 3, 4 anglers. Region of residency grouped as metropolitan (Minneapolis-St. Paul), and non-metropolitan residents.

| | | | | | Angler Demographics | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fishery** | **Species** | **Regulation implemented** | **Date regulation** | **Creel year**[1] | **Local/ non-local**[2] | **Days fished** | **Days fished annually**[3] | **Day type lake**[4] | **Angler age** | **Species targeted** | **Party number** | **Region of residency** |
| Ann[5] | WAE | 16″ min | 2000 | 2000 | **0.044** | 0.326 | 0.241 | 1.000 | 0.186 | 0.362 | 0.830 | 0.874 |
| Ann (metro) | LMB | No Kill | 1995 | 2000 | 0.180 | **0.003** | **0.000** | 0.899 | 0.164 | **0.000** | **0.041** | 0.733 |
| Ann (metro) | LMB | No Kill | | 2001 | 0.968 | – | **0.000** | 0.348 | **0.043** | **0.006** | 0.066 | 0.476 |
| Bavaria | LMB | No Kill | 1995 | 2000 | **0.002** | 0.164 | **0.000** | **0.028** | 0.126 | 0.388 | 0.419 | 0.867 |
| Bavaria | LMB | No Kill | | 2001 | 0.380 | – | **0.000** | 0.391 | 0.127 | 0.146 | 0.398 | 0.776 |
| Big Sand | WAE | 18–26″ prot | 1995 | 2002 | 0.806 | – | – | 0.671 | 0.191 | **0.025** | 0.230 | 0.407 |
| Big Stone | WAE | 14″ min | 1996 | 2001 | **0.020** | 0.058 | **0.000** | 0.523 | **0.040** | 0.348 | 0.099 | 0.454 |
| Borden[5] | WAE | 20–23″ prot | 2000 | 2000 | 0.348 | 0.056 | 0.528 | 0.572 | 0.432 | **0.012** | 0.810 | 0.909 |
| Chisago-Lindstrom[5] | LMB | 12″ max | 1997 | 2000 | **0.000** | **0.000** | **0.000** | 0.100 | 0.593 | **0.000** | 0.302 | **0.003** |
| Chisago-Lindstrom[5] | LMB | 12″ max | | 2002 | **0.000** | 0.657 | **0.032** | 0.527 | 0.365 | 0.450 | 0.277 | 0.126 |
| Chisago-Lindstrom[5] | WAE | 16–20″ prot | 2002 | 2002 | **0.000** | 0.532 | **0.007** | 0.802 | 0.709 | 0.168 | 0.470 | **0.024**[7] |
| Farm Island | WAE | 16–19″ prot | 1996 | 2003 | **0.000** | **0.010** | **0.000** | 0.061 | 0.938 | **0.000** | 0.960 | **0.035** |
| Farm Island | WAE | 16–19″ prot | | 2004 | 0.264 | 0.589 | **0.000** | 0.929 | 0.469 | 0.399 | 0.613 | 0.929 |
| Flour | SMB | 11″ max | 1996 | 2001, 2002 | 0.147 | 0.481 | 0.518 | 0.096 | – | 0.237 | 0.343 | 0.786 |
| Green[5] | BLC | 9″ min | 1997 | 2000 | **0.016** | **0.022** | **0.000** | 0.624 | 0.783 | 0.651 | 0.526 | **0.010** |
| Green[5] | BLC | 9″ min | | 2002 | **0.030** | **0.007** | **0.009** | 0.320 | 0.915 | 0.086 | 0.110 | **0.008** |
| Green[5] | WAE | 17″ min | 2002 | 2002 | **0.007** | **0.000** | **0.010** | 0.909 | 0.648 | 0.089 | 0.715 | 0.060 |
| Hungry Jack | SMB | 11″ max | 1996 | 2001, 2002 | 0.765 | 0.644 | 0.097 | 0.729 | – | 0.595 | 0.080 | 0.749 |
| Knife[5] | WAE | 18–24″ prot | 2000 | 2000 | 0.134 | 0.091 | **0.000** | **0.042** | 0.359 | 0.128 | 0.924 | 0.772 |
| Lac Qui Parle | WAE | 15″ min | 1996 | 2001 | 0.330 | **0.034** | **0.031** | 0.862 | 0.098 | **0.000** | 0.170 | 0.380 |
| Lac Qui Parle | WAE | 15″ min | | 2001–2002w | 0.584 | 0.211 | 0.917 | 0.764 | 0.162 | 0.584 | 0.075 | 0.624 |
| Lac Qui Parle | WAE | 15″ min | | 2003 | 0.906 | 0.165 | 0.113 | 0.552 | 0.911 | **0.000** | 0.094 | **0.021**[7] |
| Little Mantrap | LMB | 12–18″ prot | 1997 | 2002 | **0.003** | – | – | 0.348 | 0.118 | 0.136 | 0.430 | **0.004** |
| Little Mantrap | LMB | 12–18″ prot | 1997 | 2003 | 0.258 | – | – | 0.913 | 0.137 | 0.699 | 0.410 | 0.146 |
| Melissa | NOP | 24″ max | | 2003 | – | – | – | 0.195 | – | 0.290 | **0.031** | – |
| Melissa | NOP | 24″ max | | 2003–2004w | – | – | – | 0.296 | – | 0.091 | 0.648 | – |
| North and South Lida | BLC | 11″ min | 1997 | 2002 | 0.647 | – | – | 0.071 | 0.803 | 0.149 | 0.613 | 0.648 |
| North and South Lida | BLC | 11″ min | 1997 | 2002–2003w | 0.920 | – | – | 0.069 | 0.259 | 0.139 | – | 0.790 |
| Pike | SMB | 11″ max | 1997 | 2000, 2002 | – | – | – | **0.020** | – | 0.273 | 0.818 | 0.177 |
| Sallie | NOP | 24″ max | | 2003 | – | – | – | 0.924 | – | 0.074 | 0.605 | – |
| Sallie | NOP | 24″ max | | 2003–2004w | – | – | – | **0.002** | – | 0.057 | 0.103 | – |
| Spider | BLC | 10″ min | 1997 | 2002 | 0.288 | – | – | 0.326 | **0.011**[6] | 0.597 | 0.185 | 0.768 |
| Spider | BLC | 10″ min | 1997 | 2003 | 0.417 | – | – | 0.382 | **0.042** | 0.154 | **0.001** | 0.163 |
| Two Island | SMB | 11″ max | 1996 | 1999, 2002 | 0.532 | – | – | 0.152 | – | 0.251 | 0.307 | 0.729 |

1 All creels are summer creels (typically May–September) unless designated with a "w," which represents a winter creel. Winter creels typically conducted from December–February. Data from multiple creel years combined for SMB fisheries.
2 Local designated as ≤ 50 miles, and non-local > 50 miles for Flour, Hungry Jack, Pike, and Two Island Lakes.
3 Days fished annually grouped as < 5, 5–10, 11–20, 21–50, and > 50 days for Bavaria and Ann (metro) lakes.
4 Days fished lake grouped as 0,< 5, 5–10, 11–20, 21–50, > 50 days for Bavaria and Ann (metro) lakes.
5 Fisheries within the 1837 Treaty region.
6 Older angler less aware of regulations.
7 Metropolitan anglers more aware of regulations.

often. For seven fisheries, no significant differences in levels of angler awareness were found. However, for only one of these fisheries were we able to analyze the full complement of demographic factors.

Significant differences in angler awareness were consistent with expectations for all but six comparisons. For the 2000 Chisago-Lindstrom Lake largemouth bass, 2000 Green Lake black crappie, 2002 Green Lake black crappie, Little Mantrap Lake largemouth bass, and 2003 Farm Island Lake walleye fisheries, metro anglers were less aware of regulations ($P = 0.003$, $P = 0.010$, $P = 0.008$, $P = 0.004$, and $P = 0.035$, respectively) than non-metro anglers. For the Spider Lake black crappie fishery, younger anglers possessed greater awareness than older anglers ($P = 0.011$).

*Sources of Regulation Information*

We evaluated where anglers received their information on regulations for 25 fisheries (Table 4). Anglers relied primarily on the regulation synopsis (59%), lake public access signs (12%), and word-of-mouth (11%) as information sources on regulations. The regulation synopsis ($N = 11$) and lake public access signs ($N = 7$) were documented as being used most often for 18 of the 23 evaluated fisheries. Word-of-mouth was the primary source of regulation information for only 2 fisheries, but was documented as the second or third most prevalent source for 14 fisheries. Regulation information from resorts and fishing guides was the primary information source for angler parties within three fisheries (Big Stone Lake walleye winter fishery, Flour Lake smallmouth bass, and Hungry Jack Lake smallmouth bass). For North and South Lida lakes, nearly all of the anglers had used the regulation synopsis. For the Big Stone Lake 2001–2002 winter walleye fishery, 15% of angler parties were documented as using newspapers or magazines as sources of regulation information. Overall, few angler parties were documented as using the MNDNR website (2%), paper/magazines (2%), pamphlets (< 1%), radio (< 1%), or television (< 1%) as sources of information on regulations.

## DISCUSSION

We decomposed interviewed angler parties into angler parties that caught protected sized fish and analyzed whether noncompliance differed significantly based on angler party awareness. We found that unaware angler parties were significantly more likely to be noncompliant than aware anglers among a number of fisheries (black crappie, largemouth bass, and walleye) and across all fisheries combined, suggesting that unawareness of regulations can promote noncompliance with regulations. However, relationships between estimates of angler awareness and estimates of noncompliance varied greatly between and among fisheries evaluated.

Determining a relationship between angler awareness and compliance is difficult for several reasons. First, overall compliance is dependent on relative contributions from angler indifference, fish length measurement error, and angler awareness. Partitioning noncompliance into these three components is difficult, and therefore, angler indifference and measurement error may mask actual relationships between angler awareness and compliance. Noncompliance among aware anglers within a number of fisheries investigated in this study may have resulted from measurement error, given that the mean sizes of illegal fish harvested were near the size limit boundaries (≤ 0.5 in; Page et al. 2004). Second, the difficulty in predicting angler noncompliance based on angler awareness may also be a function of the inherent complexity of angler behavior, especially those behaviors associated with the harvesting of fish, and the characteristics of a fishery. Previous studies have shown that relative

**Table 4.** Percent of angler parties using particular sources for information on regulations for 23 Minnesota fisheries. Only completely aware and incompletely aware angler parties were evaluated.

| | Information Source | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bait shop | Word-of-mouth | Regulation synopsis[1] | Lake sign | Resort/ fishing guide | Paper/ magazine | Pamphlet[2] | DNR web site | Television | Radio | Other | N |
| Ann[3] | 1 | 8 | 2 | 80 | 4 | 5 | | | | | | 106 |
| Ann (metro) 2000 | | 14 | 21 | 48 | | | | | | | 18 | 155 |
| Ann (metro) 2001 | | 13 | 22 | 65 | | | | | | | | 109 |
| Bavaria 2000 | | | 29 | 28 | 16 | | | | | | 28 | 178 |
| Bavaria 2001 | | 6 | 34 | 29 | | | | | | | 31 | 125 |
| Big Stone | 4 | 16 | 52 | 5 | 3 | 6 | | | | | 13 | 461 |
| Big Stone (winter) | 2 | 29 | | 4 | 35 | 15 | | | | | 15 | 52 |
| Borden[3] | | 15 | 27 | 48 | 4 | 5 | | 1 | | | | 115 |
| Chisago-Lindstrom 2000 | 6 | 22 | 37 | 30 | 3 | 1 | | | | | | 270 |
| Chisago-Lindstrom 2002[3] | 3 | 44 | 13 | 13 | 5 | | | 1 | | | 21 | 131 |
| Farm Island | 1 | 25 | 30 | 12 | 10 | < 1 | < 1 | 1 | | | 21 | 361 |
| Flour | | 1 | 19 | 34 | 46 | | | | | | | 85 |
| Green 2000 | 8 | 20 | 22 | 43 | | 7 | | 1 | | | | 197 |
| Green 2002[3] | 3 | 18 | 20 | 30 | | | | | | | 28 | 93 |
| Hungry Jack | | 1 | 35 | | 63 | | | | | | 1 | 91 |
| Knife[3] | 8 | 19 | 4 | 60 | 2 | 7 | | | | | | 129 |
| Lac Qui Parle 2001 | 4 | 29 | 38 | 5 | 1 | 9 | | | | | 15 | 189 |
| Lac Qui Parle 2001–02 (winter) | 10 | 47 | 14 | 8 | | 9 | | | | 2 | 9 | 99 |
| Lac Qui Parle 2003 | 5 | 34 | 35 | 8 | 3 | 5 | | < 1 | 1 | 1 | 8 | 244 |
| North and South Lida | | | 94 | 1 | 5 | | | | | | | 1132 |
| North and South Lida (winter) | | | 99 | | | | | | | | 1 | 192 |
| Total Percent | 2 | 11 | 59 | 12 | 4 | 2 | 0 | 2 | 0 | 0 | 9 | 6823 |

[1] Standard fishing and regulation guide developed and distributed annually by the Minnesota Department of Natural Resources .
[2] Developed as supplements to regulation synopsis to inform anglers of specific regulations on a lake or within a region.
[3] Fisheries within 1837 Treaty region.

contribution of angler indifference and measurement error to the harvest of illegal fish appears to depend on fishery characteristics. For example, for regulated Canadian walleye fisheries exhibiting high catch rates (i.e., large numbers of harvestable fish caught), the illegal harvest was comprised of predominantly walleye with lengths near the regulation limit boundaries (≤ 0.5 in). In contrast, of the illegal harvest within walleye fisheries exhibiting low catch rates (i.e., few harvestable caught) were relatively few illegally harvested fish of lengths near the size limit boundaries (Sullivan 2002). This suggested that for fisheries where the catch of harvestable sized fish is high, and consequently the incentive to cheat is low, measurement error may be the predominant factor contributing to angler noncompliance, while for fisheries with low catch rates, the desire to cheat may be greater and therefore angler indifference may be the more important factor contributing to noncompliance. Similarly, Page et al. (2004) found that measurement error contributed substantially to angler noncompliance in one walleye fishery in Minnesota exhibiting high overall catch rates. However, noncompliance associated with angler indifference to length-based regulations was also apparent, and may have been related to angler attitudes toward highly restrictive size-based regulations, or low catch rates of harvestable sized fish. Also, the incentive to cheat is likely greater for situations where the risk of being caught is perceived to be minimal or where anglers feel the potential cost of cheating (i.e., fines) is worth the returns (Charles et al. 1999). Finally, the contribution of angler awareness to overall noncompliance may be similarly dependent on fishery characteristics such as catch rates, and concomitantly angler behaviors associated with fishery characteristics such as decision making related to harvest.

A number of other factors may have also masked potential direct relationships between angler awareness and noncompliance. First, awareness of a regulation is not synonymous with understanding a regulation. We assumed that an angler party that correctly recited a regulation understood the regulation. Some aware angler parties may not have correctly interpreted a given regulation, resulting in the illegal harvest of protected fish due to a lack of understanding. We observed a number of angler parties that released and harvested fish of sizes consistent with a misinterpretation of regulations (e.g., protected slot treated as a harvest slot). Second, a low proportion of angler parties were documented catching protected-sized fish, which may have reduced our ability to effectively evaluate the association between noncompliance and angler awareness across fisheries. The low number of unaware parties catching protected-sized fish may be related to our sample size, or may suggest that unaware anglers tended to capture disproportionately fewer protected-sized fish than aware anglers. In addition, on average, unaware angler parties appeared to typically catch smaller and less desirable sized fish than aware angler parties for a number of fisheries, which also may have reduced the potential for an unaware angler party to capture and harvest a protected-sized fish.

Angler party awareness of and compliance with regulations is likely dependent on three main factors: the type of fishery, and concomitantly the characteristics of anglers within a fishery, and the effectiveness of information sources in communicating regulation information to the angling public. Largemouth bass fisheries evaluated in this study generally exhibited relatively low levels of angler awareness (mean = 70%), but relatively high levels of compliance (mean = 98%). This may have been related to the fact that catch-and-release of largemouth bass appeared to be a common practice among Minnesota anglers, and therefore few largemouth bass would likely have been harvested regardless of the awareness of anglers (Cook and Younk 1998). For regulated walleye fisheries, angler awareness and compliance of regulations was high for those walleye fisheries outside the 1837 Treaty area (mean = 88% and 96%, respectively). These walleye fisheries are popular and attract large numbers



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of walleye anglers. Anglers interviewed on walleye regulated lakes were found to consist of mostly anglers targeting walleye. Thus, the proportion of non-targeting anglers was low for these fisheries, which may have resulted in the greater awareness and compliance within these walleye fisheries. Further, catch rates of walleye for non-targeting anglers were typically low among walleye fisheries, which likely limited the harvest of illegal fish by unaware anglers (MNDNR, unpublished data). For smallmouth bass fisheries, angler awareness was high while compliance was low. This may be related to the fact that smallmouth bass fisheries were located within remote regions of the state with limited access, which presents difficulties for enforcement efforts. For black crappie fisheries, some evidence suggests that there may have been a direct relationship between angler awareness and angler noncompliance. A direct relationship between angler awareness of regulations and angler noncompliance for black crappie fisheries may be related to the type of anglers (e.g., generalists) engaged in regulated black crappie fisheries, or the harvest attitudes of anglers towards black crappie. Unlike largemouth bass anglers, black crappie anglers may be more harvest oriented (Allen and Miranda 1996), and therefore more likely to harvest illegally-sized fish when unaware of regulations. In addition, black crappie catch rates related to non-targeting anglers were high compared to other fisheries, which would increase the likelihood that an illegally-sized fish would be caught and harvested by an unaware angler party.

We found overall, that angler party demographics that increased exposure to regulations were generally more likely to exhibit greater awareness of regulations. For more than one-half of the evaluated fisheries, anglers were more likely to be aware of regulations if they were local anglers, and fished a greater number of days on an associated lake. Local anglers and anglers that fished a lake more often may have possessed greater awareness due to increased exposure to localized information sources such as lake signs, bait shops, and knowledgeable individuals (e.g., other local anglers).

We observed that angler parties targeting regulated species were significantly more aware of regulations than other angler parties. Targeting anglers likely possess greater expectations for catching a given species than non-targeting anglers, which may have promoted greater awareness. Conspicuously, awareness among anglers targeting regulated species was significantly greater for only walleye and largemouth bass fisheries. Walleye and largemouth bass anglers may be more highly specialized than other anglers. Specialized anglers tend to be more engaged within specific fisheries in that they use specialized gear, join fishing advocate clubs, and dedicate most of their fishing effort toward specific sport fish (Smith and McKelvey 1986; Fisher 1997; Connelly et al. 2001), factors that may have helped to increase the level of awareness among walleye and largemouth bass anglers. In contrast, anglers targeting species such as black crappie may be generalists, that is, interested in catching fish in numbers or catching fish in general (Fisher 1997). Therefore, the level of engagement of anglers within a fishery may also be in part responsible for significant differences in angler awareness among targeting and non-targeting anglers.

We also found that the number of days fished annually was associated with rate of regulation awareness. Days fished has been advocated as an index of angler specialization, given that greater number of days fished increases the participation of an angler within a given fishery, and consequently increases the degree of specialization of the angler (Ditton et al. 1992). Greater awareness among angler parties that fished a greater number of days within the past year may reflect greater specialization among anglers within a given fishery.

Anglers from the Minneapolis-St. Paul metropolitan region have been shown to differ from other Minnesota anglers in regards to attitude and philosophy towards fisheries issues and angling in general (Jacobson 1999; Currie and Fulton 2001). Metropolitan anglers tended to be more progressive in attitudes toward fisheries issues in that they supported more restrictive regulations for protecting larger fish, exhibited less consumptive fishing behavior (e.g., voluntary catch-and-release), and exhibited less support for stocking. Metropolitan anglers also tended to be more educated, and invested more money toward angling than the average non-metro angler. Yet, we documented few fisheries where awareness of regulations differed significantly between metropolitan and non-metropolitan anglers, and in only two cases were metropolitan anglers more aware of regulations than non-metropolitan anglers. Metropolitan anglers interviewed for this study, and within another study (Currie and Fulton 2001), were found to generally fish fewer days (past year and on given lake) than non-metropolitan anglers, an attribute that this study found to be generally consistent with lower awareness. For fisheries within the 1837 Treaty region (e.g., Green Lake and Chisago-Lindstrom Lake), metropolitan anglers were notably less aware than other anglers. Lakes within this region are within close proximity to the metropolitan area (within 1–2 hr drive), and consequently, metropolitan anglers make up a large percentage (24–61% in 2000) of the angler parties that fished these lakes.

Day-type (weekday vs. weekend/holiday), angler age, and size of angler party were significantly associated with angler awareness for fisheries evaluated by Schill and Kline (1995). However, among fisheries examined in this study, few significant differences in angler awareness of regulations were observed for these factors. Specifically, for size of angler party, anglers within a given party tended to possess similar demographic characteristics, which may suggest they also possessed similar degrees of experience or exposure to regulations. These results suggest that there appears to be little added benefit from older or larger angler parties as far as regulation awareness of regulations.

Angler awareness was typically lower for the most recently regulated fisheries and for fisheries regulated with complex regulations. Munger and Kraai (1997) also observed that the majority of angler noncompliance documented for a regulated walleye fishery in Texas occurred within the first few months of regulation. That is, anglers overall appear to become more aware of regulations as the exposure time to regulations (i.e., information sources) increases. Our data also revealed that incomplete awareness among angler parties was generally greater for fisheries governed by complex regulations. Regulations less familiar to anglers or more difficult to interpret may cause confusion among anglers. Schill and Kline (1995) found that angler awareness for cutthroat trout fisheries was significantly greater for fisheries managed with catch-and-release regulations than for fisheries managed with a 14-inch maximum regulation.

Greater understanding of how anglers obtained information on regulations is important for evaluating the effectiveness of various sources in disseminating information on regulations. However, we should note that we only queried completely aware and incompletely aware angler parties on information sources. Therefore, the composition of sources used by unaware anglers is unknown. Although multiple information sources were used in Minnesota to inform anglers of regulations, anglers primarily relied on the regulation synopsis (59%), lake public access signs (12%), or word-of-mouth (11%). The regulation synopsis provides regulation information for fisheries across the state, and it was expected that it would be the source most often used by anglers.

The proportion of angler parties using lake signs as a source of information for regulations was also high. For largemouth bass and black crappie fisheries, where the proportions of anglers that used lake signs were appreciably large, special regulations were only recently implemented (i.e., within 2 years of evaluation). Anglers may have assumed that these fisheries possessed statewide size regulations for these species, and may not have realized that special regulations had been implemented until they read lake signs at the access sites.

For walleye fisheries within the 1837 Treaty region (Figure 1) walleye regulations were determined on an annual basis prior to the publication of the regulation synopsis. Walleye regulated lakes within the treaty region are designated within the regulation synopsis with a footnote informing anglers that they must consult lake signs or special pamphlets for regulations on walleye. The explanation of the footnote is provided once near the beginning of the regulation synopsis. The proportion of anglers that used lake signs as a source of information on regulations was high compared to fisheries outside the treaty region. High numbers of anglers using the lake signs for regulation information may be demonstrative of the effectiveness of the regulation synopsis in directing anglers to consult alternative information sources. However, unawareness of walleye regulations within the treaty region was high compared to lakes outside the treaty region. Given that the regulation synopsis is the most popular source for information on fishery regulations outside the treaty region, low angler awareness for walleye regulated lakes within the treaty region may be reflective of an inability of anglers to recognize or follow footnotes within the synopsis, thereby assuming no walleye regulation existed on a given treaty lake. Notably, no anglers were found to have used the special regulation pamphlet explaining walleye regulations for the 1837 Treaty region, which questions the utility of the pamphlet as a method for informing anglers of regulations within the treaty region.

## MANAGEMENT RECOMMENDATIONS

Reducing angler noncompliance is important, and promotion of angler awareness of regulations is pertinent for all fisheries, including those fisheries where noncompliance related to angler awareness may be modest (Gigliotti and Taylor 1990). Catch rates may influence anglers to direct angling effort toward other fish species (Hunt et al. 2002). Hence, unaware anglers may shift their efforts on catching regulated species if the catch rates of a preferred species are low. Similarly, regulations that are successful in promoting higher quality fisheries (e.g., high catch rates, larger fish) usually invite increased angler effort (Cox and Walters 1998), which may translate into more unaware anglers catching regulated fish. Fisheries managers should educate the greatest number of anglers possible to minimize angler noncompliance associated with angler unawareness.

In addition, future investigations on the influence of fishery characteristics on angler awareness may be warranted. If there are few protected-size fish caught within a lake (i.e., low catch rates), than there may be little incentive for an angler to know a regulation. For example, no protected-size fish were recorded in the creel for the Borden Lake walleye fishery, which exhibited the lowest level of angler awareness across fisheries evaluated (27%).

Management should work to reduce angler ignorance through tailoring education efforts to angler groups. Directing education and communication efforts toward angler groups that receive limited exposure to regulation information (e.g., non-local residents, non-targeting anglers) may be helpful in improving angler awareness. Angler awareness of regulations may also be improved by adopting more aggressive education initiatives immediately fol-



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lowing the enacting of a regulation, such as an increased presence of conservation officers, or performing creel surveys to increase contacts with anglers in order to promote awareness. Increased enforcement effort on Green Lake in later years may have helped in improving angler compliance with black crappie size limit regulations.

Reducing regulation complexity may also reduce confusion (i.e., incomplete awareness) among anglers. Regulations across the state of Minnesota for a given species are highly variable. As of 2005, there were over 20 different walleye regulations (size and bag limit combinations) implemented throughout the state of Minnesota. Minnesota has recently standardized a suite of regulations for some species to reduce regulation complexity.

Lastly, the fishing regulation handbook and signs placed at public access sites should be evaluated to test the effectiveness of these sources in disseminating regulation information. Although the MNDNR regulation synopsis followed established guidelines on design elements, such that it reflected generally accepted typographical practices and principles, the readability of the MNDNR fishing regulation handbook and the level of education required to understand the handbook has not been determined. A recent usability study of the MNDNR hunting regulation handbook found that many hunters thought that the language was confusing and that it needed better structure and organization (Brown 2004). Similarly, there is no data on the effectiveness of lake signs in alerting Minnesota anglers to regulations. The science of sign design has lead to detailed sign guidelines that have been adopted by the U.S. National Park Service (1988) and the U.S. Army Corps of Engineers (1995). MNDNR lake signs used several accepted practices in its signage in regards to typography, consistent language, and coloring for priority value. However, lake signs describing regulations typically use many words, and regulation signs are often displayed along with a number of other signs (7–9 signs) alerting anglers to various issues (e.g., invasive species and water navigation rules). Fisheries managers are concerned that lake signs possessing regulation information are not attracting the attention of anglers. The adoption of a reader-centered approach in the design process in conjunction with usability testing may produce a fishing regulation handbook and lake signs that are better understood, and more widely used by anglers (Wright 1998).


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